Phantom phenomena in limb amputees – a review article

Wrażenia fantomowe u chorych po amputacji kończyn – artykuł poglądowy

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Key words
limb amputation, amputation etiology, phantom phenomena, phantom pain, phantom pain treatment

Abstract
Amputation leading to the loss of a body part is associated not only with significant economic costs, but also serious consequences of medical and socio-psychological nature. It is the ultimate means to save a life or improve its quality. The most difﬁcult challenges faced by amputees include accepting changes regarding their own physiognomy and the resulting life restrictions. The patient subjected to amputation is faced with an extremely difficult adaptation process, during which s/he should strive for a maximum degree of independence. Unfortunately, a large group of patients also struggles with various types of sensations and pain located within the lost limb – i.e., so-called phantom phenomena. This is a special group of phenomena of diverse nature, “located” within the lost limb.

The occurrence of phantom limb syndrome in amputee patients is extremely common. This problem affects from 45% to even 98% of patients after amputation of one or both upper and lower limbs. The main purpose of this article is to describe phantom phenomena observed in patients after limb amputation in light of current literature. The definition, historical outline, types of phantom phenomena are presented, as well as hypothetical pathomechanisms, factors influencing the frequency and intensity of phantom phenomena and available treatment methods. The work was based on numerous text sources and the author’s own experience.

Streszczenie
Amputacja prowadząca do utraty części ciała wiąże się nie tylko ze znacznymi kosztami ekonomicznymi, ale i poważnymi konsekwencjami natury medycznej i społeczno-psychologicznej. Jest ostatecznym środkiem mającym na celu ochronę życia lub poprawę jego jakości. Do najtrudniejszych wyzwań, z jakimi przychodzi mierzyć się osobom po amputacji należy zaliczyć zaakceptowanie zmian we własnej fizjonomii oraz wynikające z nich, ograniczenia życiowe. Pacjent po amputacji ma przed sobą niezwykle trudny okres adaptacyjny, w trakcie którego powinien dążyć do maksymalnego stopnia samodzielności. Niestety duża ich grupa zmaga się także z różnego rodzaju doznaniami i dolegliwościami bólownymi wymięconymi w obrębie utraconej kończyny – tak zwanymi wrażeniami fantomowymi. Jest to szczególna grupa osób odzuwać o zróżnicowanym charakterze „umiejscowionych” w obrębie utraconej kończyny. Występowanie zespołu kończyny fantomowej u pacjentów po amputacjach jest niezwykle częste. Problem dotyka od 45% do nawet 98% z nich po amputacji jednej lub obu kończyn górnych i dol-
INTRODUCTION

Amputation is the loss of a part of the body that can occur as a result of a mechanical injury or a planned surgical procedure. Considered within the second context, it has an extremely long history and is one of the oldest medical procedures. Amputation is the ultimate means to save a life or improve its quality. It is associated not only with significant economic costs, but also serious consequences of medical and socio-psychological nature, especially in countries where prosthetics are not available, mainly due to financial reasons.

One of the most difficult challenges faced by people after amputation, include accepting changes in one’s own physiognomy and the living restrictions resulting from them. What is more, the majority of patients after amputation of a body part struggle with so-called phantom phenomena. This is a specific group of sensations, diverse in nature, “located” within the area of the lost limb. Despite constant interest in this issue, the discovery and description of complicated pathophysiological mechanisms remain valid.

This work was created on the basis of numerous text sources, mainly Polish- and English-language articles from medical journals and the authors’ own experiences.

LIMB AMPUTATION
PROCEDURE – DEFINITION, EPIDEMIOLOGY AND HISTORICAL OUTLINE

“Amputation is a medical procedure that involves the partial or complete removal of a limb.” From an operational point of view, this procedure involves surgical exposure of the bone in order to sever it or evertication of the joint. In addition, during surgery, it is necessary to properly prepare the soft tissues so that it is possible to form a proper stump.

The amputation procedure may be a planned and necessary procedure to save a patient’s life, but amputation may also be the consequence of an accident, during which the patient suddenly, or later due to treatment complications, loses a part of his/her body.

Brief historical outline

The term “amputation” derives from Latin, and specifically, from the adjective ambi – “circularly” and the verb puto, putare – meaning “cut”. The term was most probably first used in a medical context by Lowe in the work entitled A discourse of the whole art of chirurgery. There are many indications that amputations should be among the group of oldest surgical procedures. Taking the content of murals from the Paleolithic period into account, it can be estimated that the history of amputation reaches as far back as 36,000 years. In the past, amputations were also performed for other than medical reasons, for example as a form of punishment or a type of ritual.

According to the rules of Sharia law, theft was punished by amputation of the right hand or its fingers or cross amputation (right hand and the fingers of the left hand), while reoffense (so-called recidivism) resulted in amputation of the foot.

In turn, the Code of Hammurabi included a system of penalties based on the principle “eye for an eye, tooth for a tooth”, in other words, with what you perform the offense, you will have cut off. For example, theft, medical blunders or the removal of markings by a slave were punished by cutting off one’s hand. The execution of the Sandomierz nobleman Michał Piekaraki in Warsaw in 1620 for attempting to assassinate King Zygmunt III Waza, involving, inter alia, cutting off the hand (raised at the king) is also documented. According to Amnesty International, amputations as a form of punishment are still being performed in many countries.

Despite continuous advancements in medicine, amputations of limbs still currently remains an extremely important clinical issue, which lies in the sphere of interest of surgeons, orthopedists as well as physiotherapists and ortho-prosthetists.

Epidemiology

In Poland, amputations are performed very frequently: almost 400/1 million individuals annually. In comparison, for Italy, the ratio is 130/1 million, for the United Kingdom almost 120/1 million, for Spain only 50/1 million, and for the rest of the European Union from 100 to 150/1 million individuals. Poland is the only European Union country in which the number of limb amputation procedures due to atherosclerotic diseases has been increasing dramatically for years. There are many reasons for this, including, among others, lifestyle, level of social awareness, lack of experience of doctors at family medicine clinics, as well as lack of effective systemical solutions and often, economic calculation.

Indications for limb amputation surgery

The basic typology of amputation indications takes the degree of risk they pose to the health and/or life of the patient into account. Two basic types can be distinguished:

– absolute indications that we deal with when surgery must be carried out to save a patient’s life. Such amputation indications are divid-
ed into primary and secondary ones. The first are performed immediately, the second, in deferred time to prepare the patient for surgery; – relative indications, which include all situations in which the procedure is aimed at improving the functioning of motor organs and/or increasing the quality of life of a patient (Table 1)27-38.

Regardless of the type of indications observed in a given patient, the physician's decision to perform amputation should always be a last resort. It requires thorough deliberation and consideration of numerous social, psychological and economic complications. It should also be emphasized that this procedure diametrically changes the life of not only the patient, but also his/her relatives39. In connection with the above, the physician deciding on the type and extent of amputation must demonstrate particular insight12.

**Typology and range of limb amputation**

Depending on the length of time from the occurrence of indications to perform surgery, and the surgical intervention itself, traumatic and planned amputations can be distinguished. Trauma amputation is most often caused by unfortunate accidents that require immediate bandaging. In their course, the degree of amputation is imposed by the extent of damage and the need to select an appropriate prosthesis40. On the other hand, planned amputations are carried out at a time appointed by a doctor and in accordance with previously adopted medical objectives12.

Due to the manner in which the procedure is performed, open and closed amputations are distinguished. The first include guillotine and circular amputations27. Amputation leaving an open stump is performed relatively rarely and consists in severing the limb without closing the surgical wound, which aims to minimize the potential effects of abundant tissue purulence and necrosis41. Wound closure takes place a few days or even weeks after the first surgical treatment and involves the necessity to properly shape the stump42. This method is used in patients with massive crushes and extensive anaerobic infections37.

Closed amputation, or otherwise referred to as definitive, involves immediate suturing of the surgical wound. This technique is used in patients with no inflammatory changes in the area of planned amputation and with a satisfactory degree of blood supply to the operated tissues15.

"Myoplastic" and "traditional" techniques are also worth mentioning. They are mainly different from each other in the method of forming the cutaneous-fascial-muscular stump. In the first case, above the extremity of the exposed bone, the operator combines opposing muscle groups, which should also be attached to the bone. As a result, the myoplastic technique allows to obtain a strong and painless stump with proper blood supply, which, in the future, will enable the patient to use full-contact prostheses39.

Apart from the choice of time and manner of performing the procedure, the range of amputation is also very important. In this context, two basic types can be mentioned, that is, small or extensive amputations. Extensive amputations include surgery performed below elbow level, below knee level and higher. Surgeries carried out below these limits are called small amputations26.

Slightly different factors determine the range of amputations performed in the area of the upper and lower limb. In these amputations, one should be guided by the principle of "save as much as possible", especially regarding the thumb, which fulfills an essential role in grip mechanics via opposition to the index finger. In turn, the level of lower limb amputations depends on their supportive and

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**Table 1**

<table>
<thead>
<tr>
<th>Type of indication</th>
<th>Absolute indications (posing a direct threat to the patient’s life)</th>
<th>Relative indications (not constituting a direct threat to the patient’s life)</th>
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<tbody>
<tr>
<td></td>
<td>primary (requiring immediate surgery)</td>
<td>secondary (the operation may be deferred in time, but must be carried out)</td>
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<tr>
<td>Examples</td>
<td>• so-called amputations performed when the victim has already lost his limb during an accidental event28,</td>
<td>• malignant tumours, e.g. osteosarcoma44,</td>
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<td></td>
<td>• extensive crushing of limbs occurring during various accidental events26,</td>
<td>• serious thermal and radiation burns,</td>
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<td></td>
<td>• gas gangrene with rapidly progressing course29,</td>
<td>• IV degree frostbite,</td>
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<td></td>
<td>• septic shock or fulminant purpura which is a complication of severe sepsis31,32,</td>
<td>• critical limb ischemia, including diabetic foot35,</td>
</tr>
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<td>• lack of adequate medical staff/facilities, e.g. during wars or large scale natural disasters37.</td>
<td>• amputations at the base of which we can find inborn defects of the osteoarticular system, precluding the performance of motor functions36,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• acquired distortions limiting mobility or causing persistent pain, as well as ulcers, osteoarthritides and pseudoarthrosis threatening to undergo tumorous transformation37,</td>
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<tr>
<td></td>
<td></td>
<td>• aesthetic or psychological purposes, e.g. apotemnophilia28,</td>
</tr>
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**Notes:**

1. Myoplastic amputation: A technique that involves the preservation of as much muscle tissue as possible to maintain the strength and function of the remaining limb.
2. Traditional amputation: A technique that involves the removal of a significant amount of muscle tissue, often resulting in a weaker limb.
3. Critical limb ischemia: A condition where the blood supply to the lower extremities is severely reduced, often due to obstructive arterial disease.
4. Septic shock: A life-threatening condition characterized by sepsis and low blood pressure.
5. Fulminant purpura: A type of thrombocytopenic purpura that progresses rapidly and can be life-threatening.
6. Sepsis: An infection that spreads within the body, leading to septic shock.
7. Osteosarcoma: A type of bone cancer that usually occurs in the extremities.
8. IV degree frostbite: A severe type of frostbite that can cause tissue necrosis.
9. Critical limb ischemia: A condition where the blood supply to the lower extremities is severely reduced, often due to obstructive arterial disease.
10. Acquired distortions: Abnormalities that occur after an injury or condition has been present for an extended period.
11. Aesthetic or psychological purposes: The desire for cosmetic appearance or psychological benefit.
12. Apotemnophilia: A condition in which an individual seeks to undergo amputation for aesthetic or psychological reasons.
13. Full-contact prosthesis: A type of prosthesis that provides full contact with the foot, allowing for better balance and stability.
14. Inborn defects: Conditions that are present from birth and are usually genetic in origin.
15. Tumorous transformation: The process by which a benign tumor may become malignant.
16. Save as much as possible: A principle guiding the management of amputations to preserve as much functional tissue as possible.
17. Thumb opposition: The ability of the thumb to move in a manner that mimics the function of the index finger.
18. Index finger: A finger located on the opposite side of the palm from the thumb.
19. Prostheses: Artificial devices designed to replace missing body parts.
locomotive functions, and should create the possibility of optimal prosthetic application\(^7\). In this context, the so-called amputation blind spots should also be borne in mind.

Regular surgical practice proves that upper limb amputations are most often performed in the case of traumatic indications, most of which are affected by finger injuries. On the other hand, the most frequently registered indications for performing amputations among the lower limbs are chronic illnesses resulting in ischaemia and necrosis, which affects up to 90% of patients\(^17\).

**PHANTOM PHENOMENA – DEFINITION, DIVISION AND HISTORICAL OUTLINE**

The amputee is faced with an extremely difficult adaptation period, during which s/he should strive for a maximum degree of independence. Unfortunately, this struggle is often accompanied by various types of pain and sensations located within the lost limb and/or stump, which may lead to depression, a feeling of hopelessness and deterioration of quality of life due to its chronic nature.

In literature on the subject, these types of phenomena are variously defined and named, but specialists most often use the terms: phantom sensations, phantom phenomena, phantom limb pain (PLP) and phantom limb syndrome (PLS)\(^3\). It is worth noting that the word "phantom" was first used by the American neuroscientist Silas Weir Mitchell (1829-1914) in 1871\(^8\), and the medical issue itself was already presented in 1551 by the prominent French physician Ambroise Paré\(^4\).

The occurrence of phantom syndromes in amputees is extremely common. This problem affects from 70%\(^10\) to even up to 98% of patients\(^46\), or according to other authors, from 45%-85% of patients after amputation of one or both upper and lower limbs\(^3\).\(^7\). According to Kuffler\(^1\), phantom pain usually occurs at two time periods: up to a month following amputation and later, approximately a year after surgery. Although in most patients the frequency and intensity of phantom pain decreases over time, severe pain persists in 5%-10% of them\(^41\). These ailments may also occur immediately after the surgery or only after a few years. Interestingly, this type of discomfort usually disappears over time, usually 2 to 3 years, but may also assume chronic form\(^44\). According to Kuffler\(^1\), if the pain persists beyond 6 months, the prognosis regarding its decrease is unfavourable.

**Hypothetical patomechanisms of phantom phenomena**

Initially, it was thought that the bases of phantom phenomena are mental disorders\(^19\). Interestingly, from a biological point of view, the issue of phantom sensation was for the first time observed by Ambroise Paré, who claimed that pain in amputated limbs is a consequence of irritation of nerve endings located within the stump\(^15\).

Currently, there are many scientific theories attempting to explain the pathomechanisms of phantom phenomena following amputation. It seems that phantom pain appears and is sustained by various mechanisms\(^43\). This pain induces changes in particular parts of the nervous system (peripheral axons, dorsal root ganglia, spinal cord and cerebral cortex) occurring at two separate periods following amputation\(^4\). The first takes place within the first month after amputation and seems to be a key period in the development of phantom pain. The second, occurring at a later period, is associated with changes in neurons and neurological circuits responsible for its maintenance. Such a state of affairs is caused, among others, by loss ofafferent stimulation and collateral hyperplasia of the spinal cord’s neurons, increased activity of inflammatory cells in the ganglia, hyperactivity of nociceptive neurons and formation of neuroma in the stump, including those reported by Robert Melzack and Vilayanur Ramachandran\(^4\).

Neuromas are pathological inflammatory lesions in the area of the nerve endings that are sensitive to various stimuli, such as, for example, touch- or temperature-related changes. They occur in 13% to 32% of patients after amputation and greatly hamper the process of fitting a prosthesis\(^3\).\(^4\). The truthfulness of this concept is supported by, among others, the intensification of phantom phenomena in stressful situations, in which released norepinephrine translates into increased activity of cells forming neuroma. In turn, the low effectiveness of the stump re-operation denies the thesis for this reason. Therefore, these treatments should be preceded by broadly understood neuropathic pain therapy\(^1\).

The next theory assumes abnormalities in the functioning of the spinal cord, which may include, among others: its damage, hyperactivity of cells, changes in discharge patterns and misinterpretation of signals via the cerebral cortex\(^4\). This idea seems to not be supported by the fact that phantom phenomena are also experienced by individuals with tetraplegia.

In 1990, Robert Melzack proposed a different concept for explaining the pathomechanism of phantom phenomena, the so-called neuromatrix concept\(^10\). According to its assumptions, there is a “neuromatrix” in the brain, the task of which is not only to respond to the stimuli that reach it, but also to generate a feeling that the human body is a whole and belongs to it. All kinds of disruptions in the functioning of this “neuromatrix” may contribute to the occurrence of phantom phenomena.

According to Ramachandran, the basis of phantom sensation lies in reorganization among the areas of the somatosensory cortex, which occurs due to amputation. The somatosensory cortex is located in the frontal lobe. Each area is responsible for sensory sensation from different parts of the body. Work is similarly organized, close to the motor cortex. In a situation when a certain zone stops receiving impulses due to e.g. amputation, it takes over the function of neighbouring areas. In connection with the above, it may happen that a patient following hand amputation will experience phantom sensations, while for example, stimulating certain are-
as of the face. Recent research confirms the phenomenon of cortical remodelling after amputation of the upper limb, consisting in partial invasion of the zone representing the mouth, on the adjacent expiring zone representing the amputated hand.

Types of phantom phenomena

The typology of phantom phenomena most frequently quoted in literature on the subject was formulated at the end of the 20th century. According to its assumptions, two basic types of phantom phenomena are distinguished: phantom sensations and phantom pain.

Phantom sensations

Phantom sensations can be defined as a group of illusory and painless sensory experiences, including part or the whole amputated limb (Figure 1 and 2). They can take on a variety of forms, including: phantom limb sensation and phantom limb awareness. The first are experienced by patients as sensory sensations, such as tingling, itching, tickling, feeling of movement, a feeling of warmth or cold. In the second case, patients feel the presence of the lost limb. This phenomenon is often accompanied by so-called telescoping, i.e. progressive shortening or lengthening of the felt phantom limb (the closest part of the phantom is perceived as missing, e.g., the tibia, while the distal part e.g. the foot, as located at the base of the stump). This may be due to smaller representation in the cortex of proximal parts of the limbs with respect to the distal parts. In addition, it has been observed that lower limbs have a faster telescoping tendency than the upper one, which also supports the above-mentioned theory. The dynamics of telescoping greatly varies in amputees. In general, it develops within the first weeks after amputation and progresses gradually over many years, but it can also develop within a few hours. Tele-scoping is important from a clinical point of view because it is usually associated with an increased level of phantom pain.

An additional phantom sensation may also be voluntary limb movement.

Phantom pain

Phantom pains, i.e. painful sensory sensations, are most often located in distal parts of a non-existing limb or other amputated body parts. It was believed that this problem affects only 2% of patients, however, more recent studies indicate that this problem occurs in over 4/5 patients following amputation. It is worth emphasizing that these pains appear relatively quickly and as time passes, they usually weaken and sometimes even disappear completely.

It is assumed that the basis for the occurrence of phantom pains are pathological remodelling processes including changes in the peripheral and central nervous systems, however, the details of the pathomechanisms mentioned above are still not fully understood. There are a number of factors that can increase the risk of phantom pain, including, among others:

- the presence of severe and/or chronic pains in the pre-operative period in the area of the affected limb,
- stump pain,
- amputation due to crushing, impaired peripheral circulation or tissue necrosis,
- poor condition of stump healing,
- so-called post-traumatic “pain memory”,
- iatrogenic errors in the form of, for example, an incorrectly bandaged stump,
- infections and other complications within the area of the postoperative wound,
- general poor mental state of the patient, including, for example, anxiety disorders, depression.

The nature of phantom pain can be extremely diverse, hence, numerous classifications have been created for its more precise description. Among the terms describing pain often mentioned by patients after amputations, the following should be mentioned: stinging, burning, prickling, cutting, vibrating, contractive, compressive, burning twisting, dull, tickling, itching, stabbing, in the form of electric discharges, paralyzing, freezing or “pain as before surgery”. It should be noted that due to the unwavering interest in the subject-matter, the presented typology is an "open list". This is confirmed by information included in the mate-

Figure 1
Incomplete phantom sensation involving feeling a given body part – in this case, amputated toe and heel.

Figure 2
Phantom sensation consisting in sensing the limb after applying a prosthesis. However, the phantom phenomenon does not always perfectly correspond with the prosthesis.
Stump pain

Stump pain is often classified in literature as phantom pain, which makes diagnosis and assessment of both types of pain indistinct. For this reason, it is worth emphasizing that stump pain concerns only the existing part of the amputated limb, while phantom pain – only its non-existent part.

Stump pains may appear at any time after surgery and are observed in approximately 60% of limb amputation patients. They are usually receptor-like, but sometimes also have a neuropathic basis60. The most frequent causes of this type of pain include:
– changes in the blood vessels caused by, among others, progression of atherosclerosis, thromboembolism,
– inflammation of the stump tissues, including, among others, inflammation of bone tissue and pressure ulcers, occurring as a result of long-lasting pressure,
– incorrectly shaped stump, complications after transplantation of the skin onto the stump (hard adhesions or unmatched skin patches) and/or surgical technique errors (Photo 1-4),
– proliferative factors, e.g. neuromas and callus produced during the process of stump healing,
– further development of cancerous tissues (in patients after amputation of tumorous etiology),
– mechanical factors, including, among others, unskilled bandaging forming the stump, errors in prosthesis adaptation, changes in the volume of the stump (e.g. in dialysis patients) and associated prosthetic difficulties (Photo 5),
– others, such as joint pain, high body mass and dermatological changes within the area of the post-operative scar60.

It is also worth mentioning other post-amputation complications involving the stump, such as jumpy stump, a syndrome of mechanical disorders of unknown origin, which manifests itself in a series of cramps of various nature, e.g.: myoclonic, choreic or trembling72.

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Some factors influencing the frequency and intensity of phantom phenomena

Numerous factors were found showing a connection with the occurrence or intensity of phantom phenomena in patients following limb amputation (Table 2).6,60,73,75

The occurrence and intensity of phantom phenomena can also be influenced by:

- mode in which the amputation was carried out — persons who lost their limbs during injuries are more exposed to phantom phenomena than those for whom the amputation was planned48;
- type of prosthesis76,77;
- lateralization — patients who have lost their dominant limb are more likely to experience phantom phenomena74;
- body part subjected to amputation (concerning the upper limb more often)4,79;
- the range of amputation — phantom sensations are stronger in patients with amputation reaching above the elbow joint and weaker in patients where the stump does not reach the knee joints80;
- time of day — the intensity of phantom sensations is often stronger in the evening and at night70;
- sex — they occur more frequently in females4,51;
- occurrence of limb pain before amputation82;
- time from amputation83;
- lack of physical activity84.

Table 2

<table>
<thead>
<tr>
<th>Reasons for intensification of phantom phenomena with particular reference to phantom pain69</th>
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<tr>
<td>Factors intensifying phantom phenomena (with particular emphasis on phantom pain)</td>
</tr>
<tr>
<td>• chronic emotional stress6,60,73;</td>
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<tr>
<td>• anxiety73;</td>
</tr>
<tr>
<td>• depression1,6</td>
</tr>
<tr>
<td>• feeling of uncertainty6;</td>
</tr>
<tr>
<td>• body acceptance issues4;</td>
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<tr>
<td>• lack of psychological support6;</td>
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<tr>
<td>• sleep deficiencies and disorders72-75;</td>
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<tr>
<td>• fatigue80,74;</td>
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<tr>
<td>• sensory-motor disturbances73;</td>
</tr>
<tr>
<td>• defecation7</td>
</tr>
<tr>
<td>• micturition disorders53;</td>
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<tr>
<td>• ejaculation6;</td>
</tr>
<tr>
<td>• coughing attacks72;</td>
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<tr>
<td>• yawning73;</td>
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<tr>
<td>• stump manipulation40;</td>
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<tr>
<td>• mechanical or thermal stimuli60,74 (with properly bandaged stump, the risk of a phantom syndrome is probably reduced, whereas exposure to various stimuli increases this risk);</td>
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<tr>
<td>• climate changes85;</td>
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<tr>
<td>• total relaxation of the body during rest73.</td>
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Painless phantom sensations rarely constitute a clinical problem and therefore, the treatment of phantom phenomena is most often related to painful sensory sensations and phantom pain. To date, no fully effective method of treatment has been developed, permanently alleviating phantom pain and improving the quality of life of patients with this type of pain85. Currently applied treatment methods of painful phantom sensations can be divided into: pharmacological, neurological, physical, neurorehabilitative and psychotherapeutic5,7.

Pharmacological treatment (local anesthetics86, acetaminophen17, NSAIDs87, antidepressants88,89, opioids, anticonvulsants90-93, NMDA (N-methyl-D-aspartate) receptor antagonists92,93; calcitonin93,95, beta blockers, calcium channel blockers84,96)
Conflict of interest: none

References


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